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ABSTRACT

Described is the development of secondary school science education in India from the early post-independence era to date. Development of science instructional materials, science curricula, science academic programs, and science teacher education programs are reviewed. (SL)

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Asian Centre of Educational Innovation for Development

Curriculum Development Centres 1

School Science Education in India

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The Asian Centre of Educational Innovation for Development (ACEID) has been established at the Unesco Regional Office for Education in Asia (Bangkok) to co-ordinate the activities under APEID and to assist the associated national institutions in carrying them out.

The main objectives of APEID are :

- to promote awareness of the need for educational innovation;
- to promote understanding of innovative practices, and to encourage experimentation and adoption of educational innovations;
- to help strengthen national capabilities for the creation and use of educational innovations;
- to identify and stimulate innovative activities and co-operative action among Member States; and
- to promote the transfer of experiences.

Studies of Curriculum Development Centres in Asia 1

School Science Education in India

Department of Education in Science and Mathematics
and Workshop Department
National Council of Educational Research and Training

Study prepared for the Asian Centre of Educational Innovation for Development (ACEID)

Unesco Regional Office for Education in Asia
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PREFACE

The present study is part of a series of five studies on curriculum development institutions in India, Malaysia, Pakistan, Sri Lanka and Thailand, prepared at the request of the Asian Centre of Educational Innovation for Development by the institutions themselves or by teams of educators in the countries.

Changes in the content of education resolve themselves ultimately as changes in curriculum—how and what learning experiences are selected and organized, how they are transmitted and to whom. Curriculum issues are thus to be found in the central core of all movements towards educational reform and development.

During the last two decades, many countries in the Asian region have been engaged in reorienting their educational system to national development goals. In this process, the inadequacies of traditional procedures for curriculum formulation through ad-hoc committees have become all too obvious. These procedures tend to cast the curriculum in a rigid and compartmentalized mould; they leave little room for systematic try-outs and for incorporating new insights derived from research or the experiences of teachers; and they dislink the formulation of curriculum, on the one hand, from the materials and methods in which any curriculum must find its concrete expression and, on the other hand, from the evaluation procedures by which the outcomes are adjudged. Further, curriculum has now a growing corpus of techniques which in its own right calls for expertise of a kind that is over and above what specialized knowledge in a subject area by itself can provide. In consequence, many countries are establishing institutional structures designed to make curriculum a continuing process of development in education reform and change.

The curriculum institutions which are covered by the five studies in this series present contrasting as well as comparable

features. Originating in the initiative of the respective governments, their institutional forms vary according to the constitutional and administrative structure of each country. In some countries the curriculum institution is a central agency for curriculum development and implementation; in others, its role is seen as more promotional and facilitating rather than prescriptive. In either case, however, the problem in common is of implementation, of how the teaching/learning relationship between the teacher and the educand is established in a meaningful, and not just a technocratic, way.

The initial perception of need which led to the establishment of these curriculum institutions was different in different countries. In some countries, it was the wholly unsatisfactory nature of the textbooks and instructional materials; in some others, it was the need to improve the teaching of a particular subject considered important; for example, science. Whatever the original perception, the programmes of these institutions show unmistakable signs of developing towards greater comprehensiveness (as opposed to single-subject orientation), articulation (linkages between curriculum development procedures, instructional materials and evaluation systems), and greater integration with the schools, the teachers and the teacher training systems. It is in these areas that some of the most difficult problems of curriculum change lie. These studies are therefore offered in the hope that the experiences which are embodied in the evolution of the curriculum institutions and programmes described in them will be of interest to those who are engaged in curriculum improvement and development.

Grateful thanks are extended to the institutions and the writers who have prepared these studies, and to Dr. Sim Wong Kooi of the University of Malaya for his help to ACEID. While the views expressed in these studies are those of the authors and do not necessarily represent the views of Unesco, they will doubtless be a valuable contribution to regional co-operative effort in the field of curriculum development.

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This account begins with a statement of the position of science and mathematics education in the early post-Independence era and describes some efforts of the Government of India for improvement of science education, in particular, through the National Council of Educational Research and Training (NCERT).

One of the important features of these efforts was to develop a total package consisting of textbooks, teachers' guides, kits, kit guides and film strips. Keeping in view the large size of the country with considerable local variations in socio-economic conditions, flexibility was built-up in implementing the programme of improvement of science education.

The new science programme lays stress on experimentation and enquiry and, to facilitate these, low-cost kits have been developed. To meet the requirements of far-off rural areas, mobile science laboratories were conceived.

The teacher remains the most important figure in any educational reform and steps were taken to orient the teachers to meet the needs of the new science programme. The Teacher Training Schools which train pre-service teachers were also strengthened so that they can produce better-qualified teachers. Evaluation of child achievement was made a continuous process. Feedback received was utilized for improving experimental versions of the curriculum package. A full-scale evaluation has also been planned.

I. BACKGROUND

The position of science and mathematics education in the early post-Independence era did not present a very encouraging picture. Science education was mostly carried out by verbal methods due to a considerable shortage of teaching equipment and also because many teachers had not mastered the methods and techniques of experimentation and demonstration. There was tremendous shortage of school laboratories and laboratory equipment. With a rapid growth in the number of schools after Independence, the country experienced an acute shortage of teachers for science and mathematics. The teacher training schools and colleges could not provide training of a level that would produce a good science teachers.

Only limited funds were available with the Central Government as well as the State Governments for education; moreover, every State had its own structure of school education (10, 11 or 12 years). Although the States prescribed their curricula, there was hardly any State effort to produce nationalized textbooks authored by knowledgeable persons or by a team of specialists. The diversity in the types of schools in each State created difficulty in the preparation of high quality syllabuses, textbooks and teachers' guides, as well as in training of teachers, introduction of new methods of teaching and unified criteria for evaluation of science and mathematics education of the youth.

The Government of India was nevertheless aware of the ever-growing importance of science and mathematics for the economy and development of the country. It was well aware

that it had to provide modern science and mathematics education so as to prepare its youth for life and for mastering technical, agricultural, medical and other specializations which were necessary for the economic growth and industrial development of the country.

In 1961, an autonomous organization, called National Council of Educational Research and Training (NCERT) was established by the Government of India with the Union Minister of Education as the President of the Council. The National Institute of Education (NIE) was set up in NCERT in the field of improvement of school education. In 1963, the Department of Science Education (now renamed as Department of Education in Science and Mathematics) was set-up in the NIE. Thus a foundation was laid for the development of science education in schools.

A Central Science Workshop was also established under the NCERT to produce prototypes of school equipment and to develop low-cost kits for the primary and middle school stages, for which it was not possible to have a full-fledged school laboratory.

In 1963, the Government of India decided to seek the expert advice of Unesco on the desirable form of science and mathematics education at the school stage. Accordingly, under the technical assistance project for improvement of secondary school teaching in India, a Unesco planning mission arrived here on 23 December 1963. The mission completed their assignment, making appropriate recommendations, the significance of which is considered in the pages which follow.

II. OBJECTIVES

The first step was to determine the objectives and the task of science and mathematics education in schools. The principal objective was seen as that of providing the growing generation with knowledge of the major achievements of science, and the achievements in technology, industry, agriculture, culture and other sides of life which base themselves on the scientific advance, and are accessible to the comprehension of pupils. This will enable the young people to be well prepared:

- for life and efficient activity in modern society;
- for a continued self-education and the enrichment of their knowledge after finishing school;
- for continuing their education in higher educational institutions preparing specialists for development of the economy.

With a view to achieving this objective, the teaching of science and mathematics in secondary schools should solve the following tasks:

1. To provide the growing generation with the knowledge of the fundamentals of science and mathematics; i.e., the major facts, laws and theories accessible to the comprehension of pupils.
2. To acquaint them with major applications of science and mathematics in industry, agriculture, civil engineering, transport, means of communication, health services,

culture and everyday life and the role and importance of these sciences in modern life.

3. To teach the pupils of schools, in the form accessible to them, the methods of science and mathematics, the ability to receive independently new knowledge and the utilization of it in life and practical activity; for this purpose they are to be equipped with necessary measurement, calculation, experimental and other experiences, and the practice of independent work with books, magazines and reference books.

4. To develop in pupils habits of observation, logical thinking, inquisitiveness of mind, speech, interest in science and mathematics and technology, aptitude and the ability to study them.

5. To shape in the pupils the norms and rules of individual and social conduct, based on the continuous utilization of science conclusions in private and social life (such as sanitation, hygiene, protection of nature, or resorting to modern technical means).

6. To assist in every possible way in vocational, physical culture and the aesthetic education of the pupils.

7. To make an important contribution to the whole work of school in shaping a modern scientific world-outlook of the pupils.

The science and mathematics education was to be divided into three stages:

Stage 1 : Classes I-V

Stage 2 : Classes VI-VIII

Stage 3 : Classes IX-XI[1]

At the first stage stress should be laid on obtaining information about the non-living nature (water, air and earth), plants and animals, man, sanitation and hygiene. Under mathematics, the student should study arithmetic with elements of geometry.

At the middle stage a disciplinary approach to the teaching of physics, biology and chemistry was adopted. The teaching of biology may be organized as below:

Class VI	–	Elements of botany
Class VII	–	Zoology and animals
Class VIII	–	Anatomy and physiology of man with the framework of knowledge about sanitation and hygiene.

The teaching of physics was also to be started from Class VI. The teaching of chemistry may be started a year after the beginning of physics teaching so that one can use the knowledge of physics to study the properties of matter.

Under mathematics, algebra (up to quadratic equations) and plane geometry should be taught. In the third stage,[2] a number of streams viz. science, humanities, technology and others should be provided. In the science stream, physics, chemistry and biology should be taught.

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1. Recently the Government of India have decided to introduce a new 10+2 pattern of schooling followed by 3 years for the first degree at the university level. Thus in the 12 years of schooling one more stage is to be added. Stage 3 will be for Classes IX and X and Stage 4 for Classes XI and XII.

2. Under the 12-year schooling pattern, Stage 3 continues to provide a general education with no division into streams. Stage 4 provides preparation for different streams.

Methods of teaching science and mathematics

1. In teaching science subjects, observation and experimentation in combination with theoretical analysis and generalization should be widely used. Experimentation in science should take the following forms:
    a) Demonstration experiments;
    b) Short and simple laboratory experiments;
    c) Long independent laboratory practical studies.
2. Methods of teaching should develop in the pupils the qualities of keenness of observation and thought, independence of thinking, inquisitiveness of mind and initiative.
3. The discovery approach to teaching should be widely utilized. Laboratory experiments should be carried out in the form of research.
4. Evaluation of pupils' knowledge should be a continuous process. This evaluation should consist of both written and oral form, laboratory work and observation.

The mission also recommended the preparation of methods guides for teachers on general problems of science and on methods of teaching different science subjects as per themes and units provided in the syllabus.

Principles of textbook preparation in science and mathematics

The following recommendations were made.

1. A textbook should fulfil the task of linking up science with practical life.

2. A textbook should not only provide established facts but should make children aware of the important present-day problems of science.
3. Textbooks in biology and chemistry should highlight problems of hygiene, sanitation, safeguarding of nature, conservation of resources, pollution and other similar problems.

The equipping of schools for teaching of science and mathematics

It was recommended that a demonstration table be provided to each science teacher; heavy and expensive tables need not be provided at the school level; rather, a small table with a bench attached thereto is considered adequate.

Establishment of a Central Science Workshop (now redesignated as Workshop Department)

The Central Science Workshop was to carry out its work on four major lines, as follows:

1. The study of equipment manufactured by industry for teaching science, and exploring how the quality can be improved;
2. Design, manufacture and experimental trial of new teaching equipment;
3. Generalization and utilization of the best Indian and foreign experience for designing and production of teaching equipment;
4. The development of new designs for manufacture by industry.

Training of science and mathematics teachers

It was recommended that correspondence and evening colleges should be started in order to train teachers of Classes I to VIII, B.Sc. teachers without B.Ed. or B.T. degrees; teachers trained in the humanities and desirous of acquiring training in science and mathematics. It was also suggested that in-service training of teachers should be organized on a regular basis so as to raise the standards of teachers.

Research in the field of science and mathematics education

Some of the problems which could be undertaken were identified as the following:

1. Objectives and tasks of science and mathematics education for different school levels in connection with a speedy growth of science and mathematics knowledge.
2. Relating the teaching of science and mathematics to practical life;
3. Preparation of the syllabuses in science and mathematics in secondary schools;
4. Methods of teaching of science and mathematics in schools and their effectiveness;
5. Methods of studying the effectiveness of science and mathematics education in schools;
6. Utilization of new audio-visual aids in science and mathematics education;
7. Programmed instruction in science and mathematics.

III. SPECIAL FEATURES

Development of curriculum

Once the problems in the field of mathematics and science were identified and objectives for imparting science education were defined, a project for curriculum development took shape and work began in the Department of Education in Science and Mathematics in September 1965. One of the important features of the project was that it aimed at the development of a complete set of curriculum materials. Until then the various State Departments of Education and the State Boards of Education only prescribed the syllabus to be covered, leaving the preparation of textbooks in the hands of private publishers who were quite often motivated by profit considerations rather than production of standard material. Under the Curriculum Development Project now envisaged, not only was the syllabus to be defined but the textbooks were to be prepared by an Experts Group. This was to be followed with the preparation of teachers' guides giving extensive directions as to how to teach various topics covered in the textbooks. In order to give adequate emphasis to observation and experimentation, it was necessary to build-in sufficient demonstration and laboratory work in the teaching-learning situation. However, in view of the very large number of primary and middle schools in the country, it would not be financially possible under the present circumstances to provide laboratories. Therefore, it was decided to work on the development of kits of equipment for different subjects which could be packed in small boxes, easy to carry and handle. It was also proposed to develop kit guides for using the material

Teacher demonstrates science concepts with the help of locally available material

Children are engrossed in experimenting and observing

provided in the kit. Keeping in view the importance of films and film strips in education in general and science education in particular, it was decided to develop a number of films and film strips which would help the teachers to bring the applications of science in the world at large into the classroom.

Built-in flexibility in implementation

Side-by-side with the preparation of curriculum materials at the Department of Education in Science and Mathematics assisted by Unesco experts, it was also decided to develop instructional materials by setting-up study groups in university centres/research organizations. Thus the States who were to introduce the new programme were provided with two variants, thereby giving sufficient flexibility in the implementation of the programme.

In addition to the two variants of instructional materials, the State Governments were given freedom to make such suitable changes in the curriculum materials as may be called for,

Different states produce materials in local languages

in view of the socio-economic background existing in the State. This adaptation also became necessary because of the different patterns of school system prevalent in the States. In quite a few States the primary stage consists of four years followed by another three or four years of middle school education and three years of high school education. In fact, it is not possible to generalize the overall pattern as there are numerous variations. In order to facilitate the work of each such group of school structures, flexibility was built in to allow them to make adaptations subject to the proviso that the spirit of the course is not lost.

Approach of teaching to be based on experimentation and enquiry

Since science is obliged for its successes to the utilization of observation and experiments in combination with the methods of theoretical research, observation and experimentation in combination with theoretical analysis and generalization should find wide utilization in the process of teaching physics, chemistry and biology in schools. This requirement should be fulfilled not only because it ensures complete knowledge to pupils but primarily on the ground that pupils should be taught science by a scientific method the mastery of which will create a capacity to study independently after finishing school. The books prepared under the project kept this view in the forefront and accordingly provided a large number of activities on the discovery approach to learning rather than verification of practical results. In order to facilitate experimentation and demonstration, complete demonstration kits and experimental kits were also planned.

As a logical step, the responsibility of the development of low-cost equipment, being part of the programme of curriculum

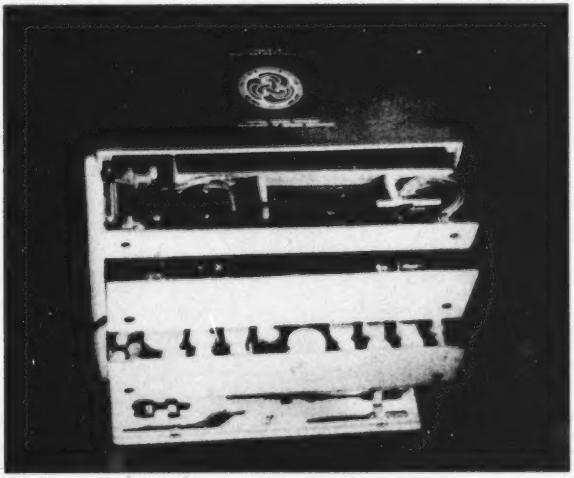
Teacher demonstrates different concepts about soil

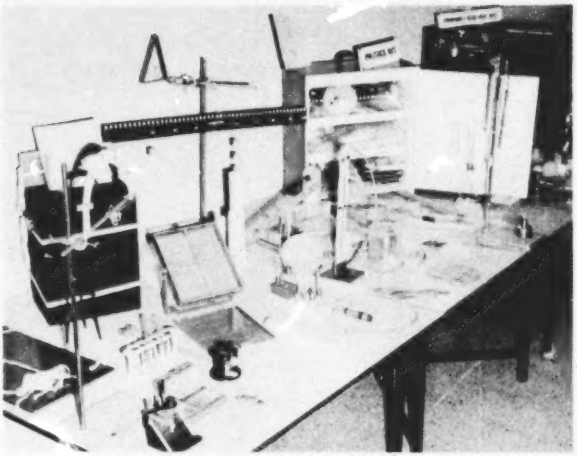
development, was given to the Central Science Workshop. Keeping in view the large numbers of primary and middle schools, it was necessary to provide inexpensive and readily available teaching materials for effective teaching of science. Purchase of sophisticated science equipment for the primary and middle classes was out of the question. The main objectives of such a development programme were as follows:

- to improvise equipment from simple, inexpensive and indigenous materials which would have high educational value for the experimental approach;
- to make alternative models and designs from different kinds of materials from the point-of-view of strength, durability and economy;

- to design such equipment for multiple usage in different experimental situations;
- to make available teaching materials in a compact portable form, so that they could be used in classroom for various experiments easily and stored in the limited space available in the classroom;
- to make it possible for the teacher to use the equipment even in the absence of a demonstration table and standard classroom furniture;
- to provide adequate pupil activity in the classroom.

The development of the kits was an integral part of curriculum development in science. The designing of the low-cost equipment, or 'science kits' progressed side-by-side with the development of instructional materials by the Department of

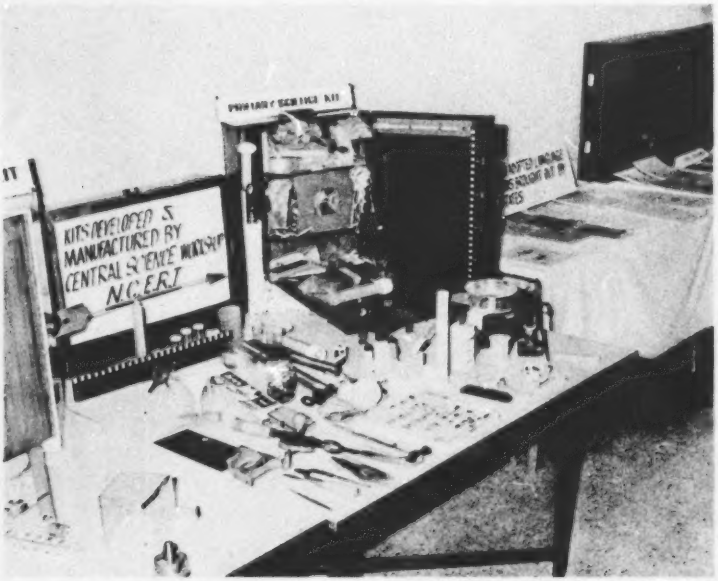




Education in Science and Mathematics. The subject experts collaborated with the workshop experts in developing these kits. The curriculum specialists suggested the classroom activity and checked whether or not some conventional apparatus for it existed. The workshop designers developed the first prototype which was then tried out in actual classroom and laboratory situations to judge if this served the basic requirements. If necessary, modifications were made and the prototypes were developed for a further try-out. Thus the involvement of the teachers and the pupils was ensured. Based on scientific feed-back and several try-outs, the most economical and durable prototype emerged.

Once the prototype was finalized, designers brought out the blue-prints for commercial production. Specifications of the materials both in terms of quantity and quality were laid down, to enable manufacturers to mass-produce the equipment for use in schools. As far as possible, standard specifications were kept in view for easy interchangeability of the components.

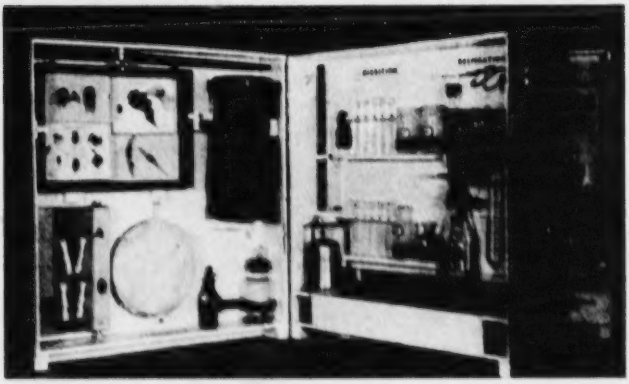
Lastly, by having completed all the items of the kit, a container-box was designed, which had several in-built features, like portability, strength, low cost, proper storage space and use as a demonstration table.



Special features of science kits

These kits are portable and act as mini-laboratories, suitable for use even in an ordinary rural school without the facilities of separate science rooms or conventional laboratories. The cost has been reduced to the minimum, utilizing most of the items which are readily available in the local markets. Items are simple and sturdy, and children can use them without any fear of injury. The science kits incorporate additional advantages, as listed overleaf.

- availability of necessary items at one place;
- multi-purpose use of items;
- economy of time in setting up;
- economy of consumable materials;
- portability from one room to another;
- provision for teacher's innovation;
- low cost and use of indigenous resources;
- easy replacement of lost or broken items.



Kit guides have also been prepared. They contain a list of the items, their sketches and detailed description. This facilitates the replacement of any part which may become unserviceable. Some of the experiments are illustrated also.

Try-out of text materials before wider introduction

In view of the widely differing socio-economic conditions and the status of science teaching in different States, it was provided that before a State adopts the programme on a wider scale, it will try out the materials in 30 selected middle schools and 50 primary schools with a view to further revision or modification of the materials.

Development of a Mobile Science Laboratory

To strengthen the programme of improving the teaching of science, the idea of a 'laboratory on wheels' was conceived. Originally, this was intended "to take science to villages" but it was found very useful for the training of teachers in distant areas. An instructor would take the mobile science laboratory through the villages and help the local teachers. The main objectives of the development of a suitable 'laboratory on wheels' were as follows:

- follow-up of guidance service to groups of teachers, who have already received some basic training in the Science Education Project;
- preliminary in-service education to those teachers working in the schools of non-project areas;
- enrichment of primary teacher's knowledge of science content;

- assistance and training in carrying out minor repairs of kit items and in using local resources for improvising some experiments;
- demonstrating the use of local environments and people's daily life experience as effective learning situations;
- providing opportunity to collect and spread to other areas any good practices or experiences found in the area;
- providing adults of the rural area opportunities of scientific literacy which would support the project;
- to educate the rural community regarding the need of an effective science education programme.

A jeep chassis was converted into a mobile science laboratory designed to meet the needs of a regular field service to help the teachers in their day-to-day programme. The other in-puts of this laboratory are; text material; teachers' guides; science kits; resource material; teacher training component; audio-visual aids; set of handtools.

It was originally planned to provide a staff of three members, comprising of (1) one driver-cum-projectionist, (2) one lecturer and (3) one technical assistant. The equipment consisted of two primary science kits, one set of middle-stage kits along with slides, filmstrips, films and film projector. Necessary charts and open working models for demonstration were also provided.

IV. DEVELOPMENT

The Department of Science Education (now D.E.S.M.) acted as the central agency for development of curriculum materials

in science and mathematics. The work in science and mathematics began in the Department of Education in September 1965. The immediate objective was to prepare a modern syllabus in these subjects and to develop curriculum materials on a pilot basis for the middle stage of the secondary schools. Later, the primary classes were also brought within the purview of the project by setting up a 'primary science cell' in the department. In a period of about five years, 28 textbooks, 12 teachers' guides, 6 equipment kits, 5 kit guides were produced.

A number of teacher training films have also since been developed. These are:

- Science Side (in colour) - prepared in collaboration with Unesco
- Science is Doing - (English and Hindi versions)
- Primary Science Kit
- Teaching Elementary Physics - (English and Hindi versions)
- Physics Kit I
- Physics Kit II
- Physics Kit III
- 'Know Your Biology' kit - (Two parts)
- Tools and Techniques of Biological Cell Study
- Chemistry kit

By the time work on the Curriculum Development Project was taken up in the Department of Education in Science and Mathematics, the report of the Education Commission (1964-66) was also received. This report laid considerable stress on development of science and mathematics education and urged immediate steps for its improvement at all stages of school education.

A conference of leading scientists and mathematicians in the country was organized by the NCERT to deliberate on the problem of improving science and mathematics education at the school level. The consensus at the meeting was that centres to be known as 'study groups' should be established in the universities and research organizations to develop better instructional materials for the students. It was recommended that the study groups should consist of scientists in the university and teacher educators. Twenty study groups in physics, chemistry, biology and mathematics were established at various university centres. Their task was to construct articulated instructional materials for the entire school stage in mathematics; and for the secondary stage from class V/VI onward in physics, chemistry and biology. Although the study groups were initially constituted for a period of about two years, it became clear that, for a variety of reasons, the task required much longer than originally envisaged.

A co-ordinating committee looked after the academic work being done by the various study groups. The biology, chemistry and mathematics groups decided from the very beginning to work as one team and to produce only one set of materials. In the case of physics, however, some divergence was seen and the study groups decided to develop materials on their own. They produced titles called "Physics through experiments", and "Physics through questions and answers". After some years the Physics Study Groups fell in line with the general pattern and decided to produce one version.

The Central Science Workshop addressed itself to the task of designing and development of science kits as early as 1968. The first kits to be developed were Physics I and a small chemistry kit for the middle school stage. In 1969 a few prototypes of primary science kits were also developed. After a number of trials, a comprehensive portable type of kit with built-in demonstration table and chalk-board was completed. It contained a set of hand tools for further improvization and repairs needed.

It was designed keeping in view the needs of small village schools.

With the experience gained in building this kit, the design of other kits posed few problems, and Physics II and chemistry kits followed. For the biology kit, however, the design of the kit box was further improved, and provided four separate surfaces and a compartment for storage.

Last of all, a Physics III kit was developed which had the advantage of experience and expertise in the field. The topics to be covered were optics, electricity and magnetism. One of the interesting items for studying optics in this kit is a ray box. By burning some incense or similar material, smoke is produced in the box. Then the sun's rays are reflected inside so that the phenomena of reflection and dispersion become visual. Another item in this kit is the 'electrophorus', which is an improvization for the Wimshurt's machine. It eliminates this costly and delicate equipment and also the problem of repairs.

The kits are of two types. One category of kits is meant for classroom demonstration by teachers and the other for pupils' experiments. Some kits could serve both the purposes by supplementing a few items from the local market. The demonstration kits have been designed for a class of 35-40 students. Items meant essentially for demonstration purposes are of large size so that a child at a distance of from 6 to 8 metres can see the details. A 'pupil kit' can serve a group of upto 6 students. The chemistry kit contains consumable materials like chemicals for a year's use. Those chemicals which are dangerous and are to be handled with care or which can be procured locally are not supplied.

The kits developed so far cover the primary and middle (junior high school) stages of the secondary schools. At the primary stage, whatever may be the syllabus, the kit will be quite useful as it will cover most of the topics. At the middle

stage, the kits are quite adequate to cover physics, chemistry and biology as well as a course in general science up to grade X.

The development of the kits was the outcome of sustained and laborious efforts by a team of subject specialists, engineers, materials experts, costing advisers and market surveyors. Ideas were generally suggested by the subject experts, who also provided necessary information about the availability of some type of apparatus in the market for this purpose. If available, this was examined by engineers for quality, cost, and suitability. If it satisfied the requirements, it was included in the kit. In most of the cases, however, the apparatus had to be designed and developed to suit the requirements of the new curricula and methodology of teaching science and considerations of cost. The prototype was tried out in the laboratories of the Department. Results of close observation were conveyed to the prototype developing team. Modifications found necessary were made and the prototype was then tried out in a school situation. Reactions of the pupils and teachers were noted and further modifications made, where necessary.

This prototype was then passed on to the Design Office for making detailed drawings. It was at this stage that the prototype underwent slight modifications from the point of view of interchangeability of its parts and process planning. Blue prints then rolled out of the section and, along with the prototype, found their place in the Inspection and Quality Control Section. This section laid down standard specifications, schedule of inspection and suggestions for further improvement.

The work of preparing curriculum materials under 'Variant I' started in the Department of Education in Science and Mathematics. The work in the study groups started a little late because study groups in each subject were scattered about the country. Moreover, the study groups found it difficult to secure experts from the university on loan for a full-time assignment or

otherwise employ people on a full-time basis, with the result that the progress was initially very slow. Under these circumstances the Variant I for the middle stage was prepared much in advance of the Variant II, and a pilot project was set up to try it out in selected Delhi schools. The pilot phase under the Secondary Science Teaching Project started with 30 middle schools in the year 1966-67 and was completed in a period of three years. The teachers of pilot schools were given orientation training before trying out the material. During the try-out the teachers met monthly and discussed in detail each segment of the materials due for class trial that month. Demonstrations were also organized for them and they were given training in the handling of the equipment.

At the end of three years, sufficient feedback was available to evaluate the instructional materials developed in the department. The materials were revised with the help of teachers in workshops and the final versions of the materials were then brought out. The feedback gave valuable information regarding the placement of topics, their sequence and manner of treatment, and the adequacy or inadequacy of demonstrations.

V. IMPLEMENTATION

India has a federal structure of government with States as constituents of the Union. A few areas which have some special features are administered by the Central Government as Union Territories; the rest of the country comprises the States. Education is a subject within the jurisdiction and competence of the State Governments.

Given the size and educational diversities in India, the implementation of a programme which is ultimately to reach the

remotest classroom is a complex undertaking. The implementation would involve about 30 administrative entities (State Governments and Union Territories), more than half a million schools, more than two-and-a-half million teachers and about 87 million pupils.

The strategy adopted in the Science and Mathematics Education programme was to implement it through key institutions in the States and the Union Territories, and to proceed by 'pilot' phases (in which grateful acknowledgement is made to Unicef for its assistance). A number of States had already moved ahead and set up State Institutes of Science Education. Others were encouraged to set up similar institutes or science wings in their State Institutes of Education. One of the States established a State Council of Educational Research and Training on the pattern of NCERT; several more are following suit.

The State Institutes of Science Education have academic staff in the various disciplines of science. They have laboratory facilities and are entrusted with providing in-service training and orientation programmes for teachers. For this project these institutes were harnessed to provide the necessary in-service training to the teachers of the project schools as well as to provide field guidance and assess the impact of the programme.

In addition to the State Institutes of Science Education, State Institutes of Education and a number of Teacher Training Institutions were selected as key institutions. Wherever necessary, the laboratory facilities of these institutions were strengthened and their personnel trained by the NCERT and the State Governments for proper implementation of the programme.

It was decided to try out the package of curriculum materials and science kits in a number of experimental schools in each State. Thus, about 1,200 primary schools and 700 middle schools were selected from the entire country, representing 30 States of the Union.

The NCERT prepared curriculum materials in English and Hindi; it was expected that their translation in regional languages would be done by the States concerned. In the process of translation, a number of States also modified the materials in the light of their specific requirements. The translated versions in all regional languages (11 languages) are now available. The State of Sikkim, which is the latest to join the Indian Union, has recently organized a training course for its teachers with the assistance of experts of NCERT and it is hoped that the Science Education Project will also be implemented in that State shortly.

The pilot projects needed kits as a part of the composite package. While the prototypes and designs were already available, it was not possible for any private manufacturer to make this limited number without the assurance of a ready market. The responsibility of manufacturing an adequate number of kits for experimental schools was therefore taken up by the Central Science Workshop.

Within the limited funds available for the project, it would not be possible to supply the pupils' kits to the project schools. Accordingly it was decided to include only the demonstration versions for supply to pilot project schools. It was recommended to supplement this kit at a later stage by some items so that there could be more pupil activity.

The process of bulk production of kits for the experimental schools resulted in further strengthening of various sections of the Central Science Workshop. Thus every year science kits worth a half million rupees were produced for the experimental schools.

The kits became quite popular, and there has been a continuing demand for them from a large number of institutions even outside the project areas.

The key persons from each State were trained by the NCERT. The States in turn organized training courses using

their own resource persons such as science lecturers of training colleges or schools, Higher Secondary science teachers and, in some cases, science lecturers of junior colleges. The stress in this training has been on familiarizing the teachers with the new 'content' and with handling of the apparatus provided in the kits in order to develop their confidence in laying out demonstrations and supervising the experimental work by students. Lessons in science content have also been given.

Almost all the States and Union Territories which tried out the Science Education Project at the pilot phase decided to expand the programme to more schools. This phase of the project was called the 'Wider Introduction Phase' (WIP). The number of primary and middle schools in which a State could enter into 'WIP' was allocated.

The wider introduction amply justifies the expectation that this project would be catalyzing the process of bringing about improvement in the field of science education at the primary and middle stages in school.

Originally, it was envisaged that there would first be a 'pilot phase', followed by a 'wider introduction phase' before the programme could be universalized in all the schools. To date, universalization of the programme has already been taken up in four States at both the primary and middle-school levels and in 8 States at the primary level.

Some interesting variations have been observed in the Wider Introduction Phase. Some of the Union Territories like Chandigarh and Goa did not take up the pilot project, as their educational system was similar to the adjacent bigger States of Punjab and Maharashtra. They used the experience of the pilot projects in these States to go straight into the WIP phase.

VI. IN-SERVICE EDUCATION

Training of academic staff at various levels

The leadership training of the staff of the four Regional Colleges of Education was organized by the Department of Science Education with the help of experts in various fields drawn from the various national and international specialized agencies involved in the development of curricula and instructional materials.

Training for science educators drawn from Teacher Training Colleges, the various State Institutes of Education and the State Institutes of Science was organized in turn in the four Regional Colleges by the staff already trained through the programme mentioned above.

Training of the Science Methods Masters of Teacher Training Schools was organized in the State Institutes of Education, with the collaboration of the State Institutes of Science in the States which have such institutes.

For the Wider Introduction Phase, training of selected primary and middle-school teachers was organized in selected teacher training schools. This has been done in all the States which have gone into the Wider Introduction Phase.

Training of key personnel and quality control of science kits

The Workshop Department of the NCERT organized training courses in inspection and quality control of science kits in 1974. The course included an introduction to engineering and drawing (i.e., blue-print reading and properties of engineering materials and engineering instruments) with reference to the six types of kits supplied under the Science Project. The participants were also taken around local factories involved in the production of scientific equipment.

An interesting feature of this course was the development of an inspection kit, contained in a briefcase for various types of inspection processes. A kit was given to the key institution of each State.

VII. LIMITATIONS

The stresses and strains of universal adoption

The present practice in most of the States in India is to prescribe a uniform syllabus for all schools. It was therefore implicit that where in a particular state the outcome of the pilot phase suggested the desirability of utilizing the materials and methods based on NCERT's design, the goal immediately became one of a general introduction of the programme in all the primary and middle schools of the State. The realities of the classroom, however, are such that educational change is brought about only when teachers' attitudes are changed. Universal adoption of materials has therefore raised problems of in-service training on a gigantic scale, and supply of kits and other curriculum materials in very large quantities. Very often a State administration tied down by rigid rules has not been able to follow a time-bound programme.

The equipping of key institutions

Some shortcomings were noticed regarding the utilization of equipment provided to the key institutions. In some State Institutes of Science Education there was lack of accommodation and the absence of adequate capability to handle the everyday items of apparatus, let alone the more sophisticated ones. In many State Institutes of Science Education the apparatus remained in cupboards with some items still unwrapped. In most

Secondary Teacher Training Colleges, although laboratories of some kind existed, no time for laboratory work was provided in the training course. It was therefore felt that the science staff of SISEs and SIEs should be trained, the curriculum of Teacher Training Colleges revised and practical work be included for training of teachers.

Problem of multiplicity of languages

As many as 14 languages are mentioned as official languages in the 8th schedule to the Constitution of India. Since primary education in the States is conducted through the regional language, any reform at this stage involved the preparation of instructional materials (non-visual) in all the languages. This obviously restricted the pace of implementation of the reform.

Financial constraints in the supply of equipment and kits

In the pilot phase and in the Wider Introduction Phase, only a limited member of schools were covered—about 5 per cent of primary and 33 per cent of the middle schools. Even on that limited scale and the unit cost held down to the barest minimum, there were difficult financial problems. Many States are now planning for the universal introduction of the Science Education Programme and are faced with a huge task in providing funds for the supply of kits to the remaining schools.

Time-lags due to extraneous factors

It was observed that there was a time-lag in the matter of training of teachers, printing and supply of books and the supply of kits. Although the academic session in a State started on a particular date for all schools, teachers were sometimes trained much later. In some cases, trained teachers were transferred out, books were provided several months after the beginning of

the session and the supply of kits was also delayed. Quite often these delays occurred owing to extraneous reasons but, whatever the cause, they did affect the implementation of the project and reduced the impact.

VIII. EVALUATION

The Pilot Project was started in a limited number of schools—50 primary schools and 30 middle schools for each State, to provide feedback for the revision of the instructional materials. Some of the States trying out the programme in the Pilot Phase made informal evaluation through discussion with groups of teachers from different pilot project schools or visits to schools. The Department of Education in Science and Mathematics also made available to States cyclostyled copies of brochures on 'Textbook Evaluation' for the science textbooks

A science class is being observed

Evaluation is a built-in feature of the project

Field trip provides rich resource material

of grades III, IV and V. An organized effort to collect feedback from all the States running the pilot project, however, could not be made till very recently.

During the Fifth Five-Year Plan (1974-79), a programme of evaluation has been started to determine the effectiveness of the Science Education Programme so that the teaching of science can be improved. It is hoped that such an evaluation will help to ensure the effective implementation of curriculum improvement programmes in future. This would also help the States to evolve an improved version of all the instructional materials prepared and tested in the light of the feedback from the extensive try-out. The revision of curricular materials for primary school science will also be guided by the principle that health, environmental sanitation, nutrition and child care are stressed so that the teaching of science is more related to the child's own life.

PUBLICATIONS RELATED TO CURRICULUM

Available from Unesco, Bangkok

1. *Teacher education and curriculum for development, 1975*
2. *Science in basic functional education: approaches, methods and materials, 1975*
3. *Science in basic functional education: links with real-life situations, 1975*
4. *Curriculum development for work-oriented education (in collaboration with NIER, Tokyo) 1976*
5. *Co-operation in curriculum explorations, 1975*
6. *Towards strategies of curriculum change, 1976*
7. *Lifelong education: the curriculum and basic learning needs, 1976*
8. *Integrated approach to curriculum development in primary education in Sri Lanka (in collaboration with IBE) 1976*
9. *Integrated science in the junior secondary school in Sri Lanka (in collaboration with IBE) 1976*
10. *Curriculum for development: analysis and review of processes, products and outcomes, 1976*

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